TFL 41 inventory audit

Introduction

An inventory is conducted by the licensee of each Tree Farm Licence (TFL) in British Columbia every 10 to 30 years, using standards and procedures that are approved by the Ministry of Forests. Regular updates are undertaken to reflect changes in the timber volume due to growth and to depletions from harvesting and natural causes.

This report presents the results of an inventory audit performed within TFL 41, which is situated in the Kalum Forest District, just north of the Midcoast TSA and adjacent to the Kitimat area. TFL 41 includes a northern portion accessible from the communities of Terrace and Kitimat, and a southern portion that encompasses ocean waterways and the township of Kemano, accessible only by air or water. TFL 41 is managed by West Fraser Mills Limited and covers approximately 1 019 740 hectares.

Purpose of the audit and application of the results

It is often asked, "How accurate is the current inventory?" To answer this important question, the Ministry of Forests has developed an inventory audit methodology specifically designed to test the overall accuracy of estimates of the total standing volume in each timber supply area.

This inventory audit methodology entails sampling three primary components of the inventory: mature forests, immature forests, and non-forest areas.

The objective of the inventory audit program is to help identify TFLs or TSAs where the forest inventory needs attention. Enough samples are taken to ensure statistically reliable results for the TSA or TFL as a whole.

The amount of data collected, however, is not sufficient to make statistically reliable conclusions about specific areas or tree species. For example, any overall differences highlighted by the audit could result from problems with one tree species, from part of the land base (such as high elevation rather than lower elevation areas), from one age group of forest stands, or from a combination of these and other factors. As a consequence, general audit results cannot appropriately be used to adjust information about the forests currently available for timber harvesting since this area constitutes only a portion of the total forested area in the TSA or TFL.

The audits provide information that may be useful to the Chief Forester when determining the allowable annual cut—offering a general assessment of the uncertainty associated with mature timber volumes, immature site index, and the non-forest classification. However, the audit results cannot justifiably be used to make specific adjustments to growth and yield and other information used in timber supply analyses and allowable annual cut determinations

Methods

Current inventory

There are 35 TFLs in British Columbia, varying in size from approximately 8500 hectares to just over 1 million hectares. Inventories of each TFL are conducted by the licensee through a multistage process. Although the methodology varies within each TFL, all standards must be approved by the Ministry of Forests. New standards currently under development will ensure a consistent minimum standard for all TFLs. Generally, polygons are first delineated from 1:15 000-scale aerial photographs. Photo-interpretation is then used to produce data on a number of attributes for each polygon. These attributes generally include species composition, stand height, age, and crown closure. Timber volume is then estimated indirectly using the photo-interpreted variables and an empirical yield model. Other approaches to volume estimation, approved by the Ministry of Forests, may also be used.

To keep estimates current, inventories are regularly updated to account for forest growth and for depletions due to harvesting, fire, and the impact of insects and disease damage. Empirical yield models, such as the Ministry of Forests Variable Density Yield Prediction (VDYP) computer model, are used to update the inventory for forest growth. Field visitation, satellite imagery, and aerial photographs may be used to update the inventory for depletions.

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Inventory audit procedures

The inventory audit tests three components of the current inventory. The first component is the mature forested areas (forest stands older than 60 years). The inventory audit tests the accuracy of the mature timber volume. The second component tested is immature stands (younger than 60 years but older than the silvicultural classification of free growing). The audit tests the accuracy of the site growth potential (site index) assignment for these stands. The third component tested is the area classified as non-forest in the inventory, which includes areas such as lakes, gravel pits, and alpine meadows. The audit tests the accuracy of the photo-interpreted classification for this component.

Mature component assessment criteria

To test the mature component of the inventory, the existing inventory's estimate of the mean mature volume per hectare for the TFL (*the inventory volume*), is compared with a new estimate of the mean mature volume per hectare obtained from the audit samples (*the audit volume*). In most TFLs the inventory volume is assessed from base yield curves derived from the VDYP yield model.

The difference between these two estimates is called the total bias. A test is conducted on this bias to determine if it is statistically significant. This test establishes whether there are detectable differences between the audit volume estimate and the inventory volume estimate, for the total forested area of the TFL.

If the total bias is found to be statistically significant, further analyses may be conducted to determine if the specific source of bias within the inventory is one of the following:

- *classification bias:* This is caused by incorrectly estimating the polygon attributes; or
- *model bias:* This is caused by poor prediction from the yield model.

In most TFLs the analysis used to determine the source of bias uses an estimate of the mean mature volume per hectare for the TFL called the *ground attribute volume*. This is calculated from audit sample attributes (stock and stand table estimates of species composition and stocking, and ground-based averages of top height and age), along with crown closure taken from the original map label, using the yield prediction model. The difference between the ground attribute volume estimate and the audit volume estimate approximates the bias associated with the yield model. The difference between the audit volume estimate and the inventory volume estimate not accounted for by the model bias approximates the bias associated with the inventory classification attributes. Once the source is identified, further analyses may be done on the inventory classification attributes or the yield model itself.

Immature component assessment criteria

Accuracy of the inventory classification for immature stands is tested by examining the site index assignment. Since the immature forest stand site index provides an estimate of site productivity, its accuracy affects the projection of long-term harvest levels.

Data gathered is examined to determine how closely the audit and inventory site indices match for individual samples, and to explore potential trends.

Non-forest component assessment criteria

The audit test for the non-forest component of the inventory assesses the accuracy of the non-forest classification assignment. An airphoto interpreter certified by the Ministry of Forests compares the non-forest inventory classification to a suitably scaled forest cover aerial photograph. Classification accuracy is rated using a point scoring scheme to determine an overall accuracy percentage. The acceptance criteria for this test is 85% or higher.

TFL 41 audit sampling procedures

The TFL 41 sample used updated maps based on the most recent inventory. A list of all polygons identified on these maps was produced and sorted on a number of stand characteristics (site quality, age, and species group). Polygons were systematically selected from this list by a process designed to produce a representative sample of the TFL.

In the 1993 audit for the mature forested component of the inventory audit, a random sample of 50 forested polygons from the total forested area in the TFL was selected for sampling.

Up to 4 full-measure prism plots and 5 count plots were established within each of the 50 sample polygons. The plots were located systematically, using a square grid and a random start point. The grid interval varied with polygon size. To reduce sample costs for large or irregular polygons, only a randomly selected portion of the polygon was sampled. A total of about 200 full-

measure and 250 count plots were established. Field data collection and compilation followed Ministry of Forests cruising and cruise compilation procedures. The objective was to obtain audit volumes that were comparable (in terms of utilization standards and merchantability definitions) to the inventory volumes produced by the licensee.

For TFL 41 (and for many other TFLs in the province), corresponding polygon-specific base inventory volumes are not available for all audit samples. In these cases, the audit volume is compared with *analysis unit volumes*. These analysis unit volumes are derived from analysis unit yield curves, which are aggregations of the base volume yield curves and are used to predict volume in the timber supply analysis process. Therefore, in situations where base yield curves are not available, *analysis unit volume* replaces inventory volume in the standard inventory audit comparisons, and is the basis on which the accuracy of audit volume estimation is assessed. In TFL 41, *analysis unit volumes* were only available for samples that fell in the forested areas considered currently available for timber harvesting (operable areas). Eleven of the original 50 inventory audit samples were in operable areas and therefore had analysis unit volumes.

To be consistent with the utilization standards used by the licensee in the timber supply analysis, audit volumes were compiled for all live trees of 17.5+ cm dbh. The audit volumes represented merchantable volume net of decay, waste, and breakage (as estimated from Ministry of Forests loss factors). Since the licensee determines analysis unit volumes using a second growth yield model, dead potential and veteran trees were not included in the compilation.

The audit volume estimates were then compared to the analysis unit volume estimates to test the validity of the current inventory. A paired sample *t-test* was used to test for significant differences. The precision of the analysis unit volume estimates—how well each analysis unit volume estimate corresponds to the audit volume estimate on a sample-by-sample basis—was assessed by measuring the statistical correlation. The data was then post-stratified to detect trends related to the operable and inoperable forested land base distribution of the sampled polygons.

From the immature forested component, a random sample of 20 polygons was selected for sampling. Up to 6 inventory ground calls were established within each of the 20 sample polygons.

The plots were located along a single transect line that was considered representative of the site productivity (site index) of the stand. A total of about 120 ground calls were established and data collection followed the standard Ministry of Forests inventory ground call procedures. The location of the sample transect was subjective. Since the magnitude of bias caused by this process is unknown, the reported results and their interpretations for the immature forested component should be used with caution.

To audit the non-forest component, a random sample of 30 non-forest polygons was selected. Standard Ministry of Forests inventory airphoto classification techniques were used to compare the 30 non-forest polygon classification assignments to corresponding airphoto checks.

Inventory audit results

Analysis of mature volumes

Analysis unit volumes were available for eleven samples that fell within the operable forested area. These samples were used in the inventory audit comparison. The results of the inventory audit for mature (greater than 60 years of inventory age) volume in the operable forested areas in TFL 41 are given in Table 1.

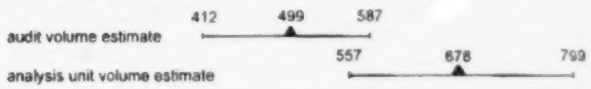
TABLE 1. Statistics for the audit volume and analysis unit volume estimates at 17.5+ cm dbh utilization, net decay, waste, and breakage, for operable forested areas, TFL 41

	Audit volume estimate	Analysis unit volume estimate
Number of samples	11	11
Mean (m^3/ha)	499	678
Coefficient of variation (%)	26	27
Standard error	39.3	54.3
Sampling error (%)	17.5	17.8
95% confidence interval (m^3/ha)	412–587	557–799

Correlation coefficient r = 0.258

Ratio of means (audit/analysis unit): 0.74

Bar graph representation of 95% confidence intervals (in m^3/ha):



For the 11 samples located within the operable forested area, the mean audit volume is 499 m^3/ha and mean analysis unit volume is 678 m^3/ha. The difference between these two estimates (179 m^3/ha) is statistically significant, 19 times out of 20.

No analysis unit volumes were available for the 39 samples in inoperable forested areas and thus no audit comparisons were made.

Analysis of operable volumes, including additional 1995 samples

Due to the relatively large sampling error and the significant difference between the audit and the analysis unit volumes in the operable component of the 1993 audit, it was decided to sample an additional 30 polygons in the operable forested area in TFL 41. The results from these additional 30 samples were combined with the 11 operable samples from the initial audit to form an augmented audit for the operable forested area, comprising 41 samples. The results of the statistical analysis of the augmented audit for the operable forested area are presented in Table 2.

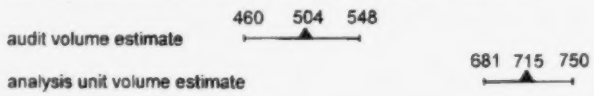
TABLE 2. Statistics for the augmented audit volume and analysis unit volume estimates at 17.5+ cm dbh utilization net decay, waste, and breakage, for operable forested areas, TFL 41

	Audit volume estimate	Analysis unit volume estimate
Number of samples	41	41
Mean (m^3/ha)	504	715
Coefficient of variation (%)	28	15
Standard error	21.7	17.1
Sampling error (%)	8.7	4.8
95% confidence interval (m^3/ha)	460–548	681–750

Correlation coefficient r = 0.145

Ratio of means (audit/analysis unit volume): 0.70

Bar graph representation of 95% confidence intervals (in m^3/ha):



For the 41 samples located in the operable forested area, the mean audit volume was 504 m^3/ha and the corresponding analysis unit volume was 715 m^3/ha. The difference of 211 m^3/ha between the two estimates is statistically significant, 19 times out of 20.

Analysis of operable volumes using VDYP as the yield model

To provide a more comprehensive review of inventory volume accuracy, further analysis of the operable samples was undertaken. This analysis, described earlier in the report under "Mature component assessment criteria," involved predicting inventory volumes using the Ministry of Forests VDYP yield model and the classification attributes as they exist in the inventory for TFL 41. To simplify the analysis, a utilization limit of 17.5+ cm dbh was applied to all species, and all volumes were estimated net of decay only.

Again, it should be noted that the VDYP yield model was not used by the licensee in the last timber supply analysis and hence was not the yield model used to derive the analysis unit volumes. The results of analysis of the mature (greater than 60 years of age on the inventory) volume for the operable forested area, using VDYP as the yield model, are given in Table 3.

TABLE 3. Statistics for the audit volume and inventory volume (using VDYP) estimates at 17.5+ cm dbh utilization net of decay only, for operable forested areas TFL 41

	Audit volume estimate	Inventory volume estimate
Number of samples	41	41
Mean (m^3/ha)	577	774
Coefficient of variation (%)	27	24
Standard error	24.2	28.6
Sampling error (%)	8.5	7.5
95% confidence interval (m^3/ha)	528–626	716–832

Correlation coefficient r = 0.258

Ratio of means (audit/inventory volume): 0.75

Bar graph representation of 95% confidence intervals (in m^3/ha)

The correlation coefficient of 0.258 for the audit and inventory estimates indicates a poor relationship among the individual samples. There is a 197 m^3/ha difference

between the mean inventory estimate for mature volume using VDYP (774 m^3/ha) and the audit estimate (577 m^3/ha). A paired sample *t-test* determined that this difference is statistically significant 19 times out of 20. This analysis indicates that when VDYP is used as the yield model, there appears to be a bias in the mature inventory volume in the operable forested areas for TFL 41, similar to that observed for the analysis unit volumes.

Further analyses indicated that the two primary components of the total bias in the inventory, the yield model (VDYP) and the classification attributes, both significantly contributed to the inventory volume overestimation. These analyses suggested that approximately 60% of the total bias was associated with the model and approximately 40% was associated with the classification attributes.

Analysis of immature inventory classification

Out of 19 stands sampled in the field, the inventory correctly identified site index within ±5 m of the audit site index for 14 stands; the inventory site index was more than 5 m lower than the audit site index for 3 stands, and more than 5 m higher for 2 stands.

Analysis of non-forest inventory classification

Thirty stands classified as non-forest were assessed for accuracy of the inventory. The resulting score was above the provincial minimum standard of 85%.

Discussion and conclusions

The objective of the inventory audit in TFL 41 was to assess the overall accuracy of the current inventory. The mature, immature, and non-forest components were tested.

The results of the initial audit for the mature component of the inventory in the operable forested areas suggest that the analysis unit volumes have been overestimated. To confirm these findings, an additional 30 samples were taken in the operable forested area. The combined samples were analyzed and indicate that the analysis unit volumes are overestimated in the operable forested areas.

Additional analyses, which examined the accuracy of the inventory using the VDYP yield model and the current inventory attributes, showed the same volume overestimation bias in the operable forested areas that was apparent for the analysis unit volumes in TFL 41. These analyses showed that both the VDYP yield model and the current inventory attributes contributed to the volume overestimation.

Audit results for the immature component of the inventory suggest an acceptable level of accuracy for site index assignment in young stands.

The audit assessment of the non-forest classification in this TFL found it to be within provincial standards.

The licensee is currently undertaking a new inventory of the management unit. It is intended that the new inventory should be complete before the next timber supply analysis is conducted for this unit. It will be possible to use the samples from this inventory audit as an independent data set to test the precision of the new inventory.

Glossary

accuracy: A measure of how close an estimate is to the true value.

allowable annual cut: The rate of timber harvesting specified for an area of land.

analysis unit: The basic building blocks around which inventory data and other information are organized for use in forest planning models, typically involving specific tree species or type groups that are further defined by site class, geographic location, or similarity of management regimes.

bias: The quality of a measurement device or procedures that tends to result in a systematic misrepresentation of what is being measured.

coefficient of variation: A relative measure of variation within a population, calculated as the ratio between the standard deviation and the mean value.

confidence interval: The range of values within which the population parameter is expected to lie.

confidence level: The estimated probability that a population parameter lies within a given confidence interval.

correlation coefficient: A measure of the relationship between two variables. A value of 0 for the correlation coefficient indicates a random relationship, whereas a value of ±1 indicates a perfect positive or negative linear correspondence.

dead potential trees: Standing or down dead timber which is estimated to contain at least 50% of its original gross volume in sound wood content.

diameter at breast height (dbh): The stem diameter (outside-bark) of a tree measured at breast height (1.3 metres above the point of germination) to the nearest millimetre.

field visitations: Ground-level field procedures designed to provide physical verification of polygon inventory attributes.

free-growing (crop): A crop of healthy trees of a commercially valuable species, the growth of which is not impeded by competition from plants, shrubs, or other trees.

inoperable lands: Lands that are unsuited for timber production now and in the foreseeable future because of their topography, inaccessibility, low value of timber stands, or designation for uses incompatible with timber production.

mean: The average value of a set of observations.

polygon: A portion of land area, delineated on mid-scale aerial photographs, of "like" or uniform land cover type.

pre-inventory assessments: Inventory activities to evaluate the existing forest inventory as a basis for deciding whether to re-inventory or update the current inventory, and to document the existing inventory, maps, and photos to support the execution of the reinventory or update if required.

public sustained yield units (PSYU): A portion of a TSA; an area of Crown land, usually a natural topographic unit determined by drainage areas, managed for sustained yield by the Crown through the Ministry of Forests. It includes all Crown lands within the currently established boundaries of the unit, and excludes federal lands, provincial parks, experimental forest reserves, gazetted watersheds and tree farm licences.

ratio estimate: The ratio between two different estimates.

representative: The quality of a sample having the same characteristics as the population from which it is selected.

sampling: The process of selecting observations.

sampling error: The error attributed to sampling procedures.

significant difference: The results of a statistical test comparing either two or more estimates, or an estimate to a fixed value. If the difference is too large to be attributed to chance, the difference is said to be statistically significant.

site index: An expression of the forest site quality of a stand, at a specified age, based either on the site height, or on the top height, which is a more objective measure.

standard error: An expression of the absolute variability of an estimate.

standard deviation: A measure of the variation of the population.

timber supply analysis: An assessment of future timber supplies over long planning horizons (more than 200 years) by using timber supply models for different scenarios identified in the planning process.

timber supply area (TSA): An area defined by an established pattern of wood flow from management units to the primary timber-using industries.

tree farm licence (TFL): Privately managed Sustained Yield Units; designed to enable owners of Crown-granted forest lands and old temporary tenures or the timber licences which replace them, to combine these with enough unencumbered Crown land to form self-contained sustained yield management units.

variable density yield prediction (VDYP) model: An empirical yield-prediction system for natural stands based on data collected in temporary inventory sample plots (TSPs) and natural, permanent growth sample plots (PSPs). VDYP predicts volume (net decay) and diameters at four utilization levels using stand height, age, and density. The aerial approach uses crown closure as the density measure.

veteran trees: Mature living trees which are remnants of an older stand.

For more information

For more information or to obtain other inventory audit reports, contact: Director, Resources Inventory Branch, B.C. Ministry of Forests, 722 Johnson Street, Victoria, B.C., Canada V8W 3E7 Phone 250-387-1314 Fax 250-387-5999. Visit our web site at http://www.for.gov.bc.ca/resinv/homepage.htm

October 1997

Inventory Audit Results :
Overview TFL 41 (Study #1 and #2)
February, 1997

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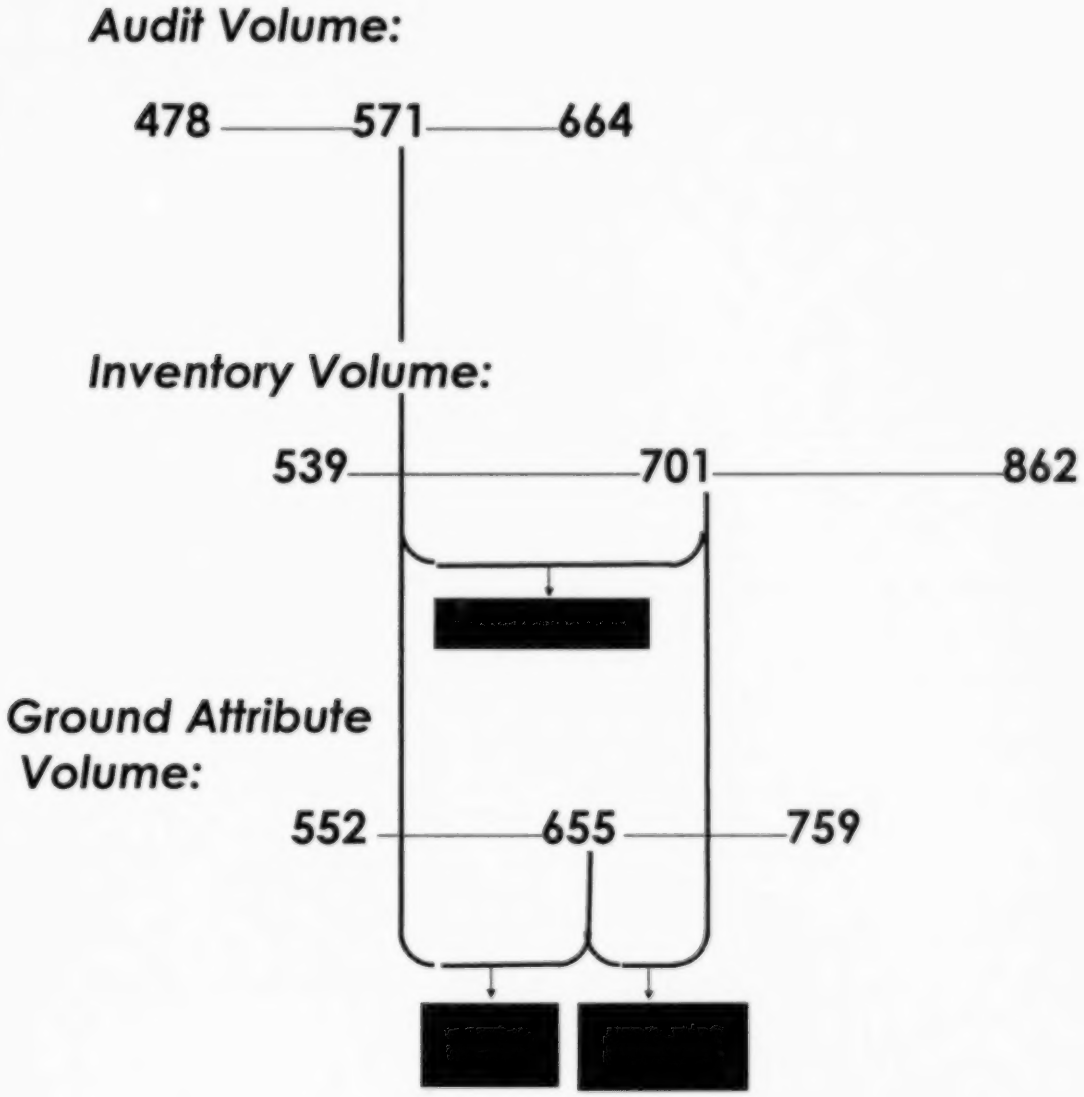
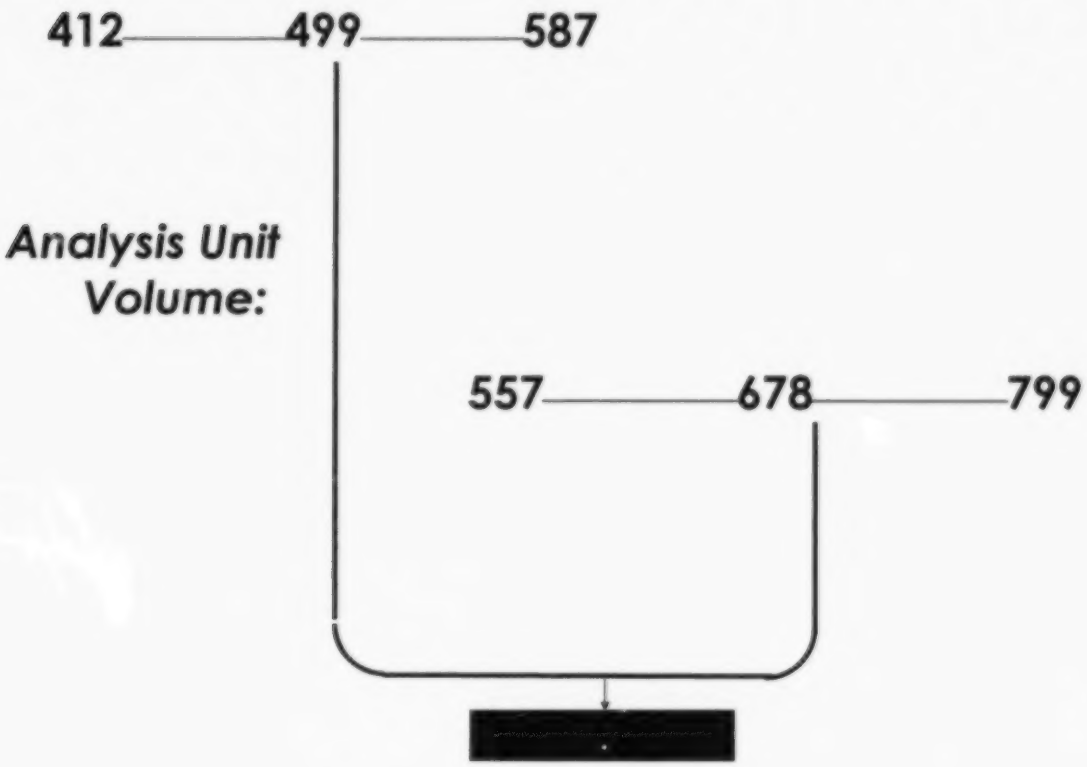
Study #1: Operable samples (n=11)



Study #1: Operable samples (n=11)

Audit Volume:
(tree class 1&2, less DWB)



Study #1: Operable samples (n=11)

Audit Volume (Kozak) vs. Inventory Volume (Predicted in VDYP)*

1. Average Volumes/ha and Confidence Interval @ 95% *(Utilization level : 17.5 cm + net merch. less decay only/ Tree Class 1,2)*

478——571——664

Audit Volume
(16.2% sampling error)

539——————701——————862

Inventory Volume
(map label attributes predicted in VDYP)
(23.1% sampling error)

2. Ratio Analysis : Ratio of Means @95%

$$R = \frac{\text{average audit volume}}{\text{average inventory volume}} = 0.81$$

1.0
↓

0.65——————0.81——————0.98

* *Since 1.0 is outside the interval, the ratio indicates that there is a significant difference between the audit volume and the inventory volume.*

3. Paired T Test @ 95% (α=0.05) for all sample polygons
mean difference = -129.7 m^3/ha
p - value for mean difference = 0.065
**since p-value > α, the difference is not significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There were no significant differences within any GTGs.

5. Correlation @ 95% (α=0.05) for all samples
Correlation co-efficient r = 0.508
p value for correlation co-efficient = 0.111
∴ correlation is not significant

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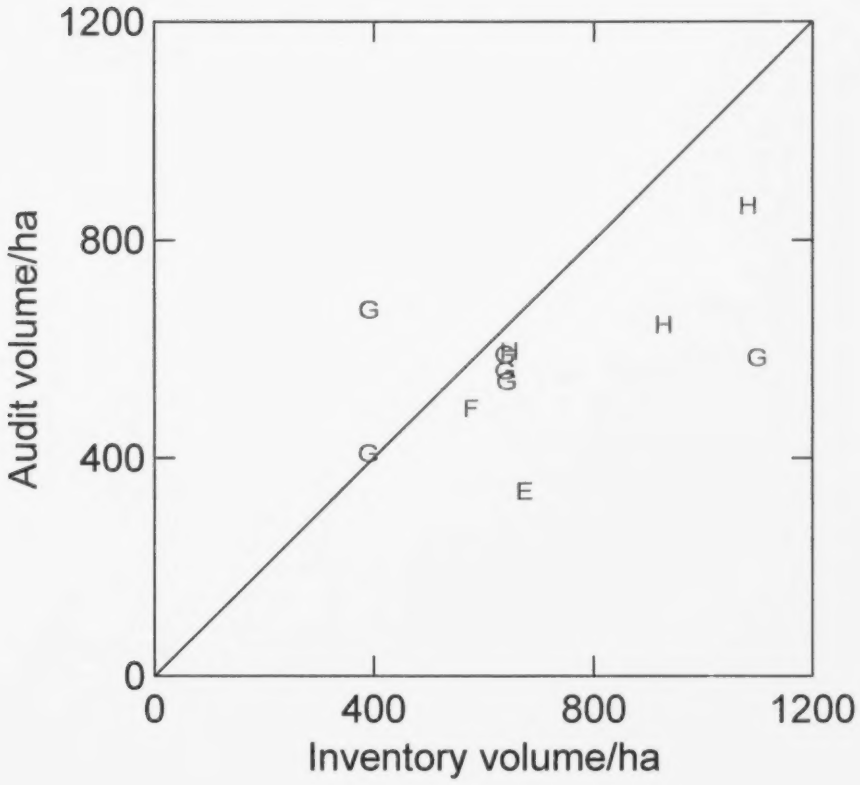
* Study #1 inventory volumes reported here were predicted using VDYP version 6.3b. Small volume differences may be observed when data here is compared with the original 1995 analysis, since VDYP has since been revised.

TFL 41 Inventory Audit: Study #1 Operable Audit Volume (Kozak) vs. Inventory Volume (Predicted in VDYP) by GTG

(Tree Class 1 & 2, less decay only, 17.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

E *C, CF, CH*
F *H (and HPI), H Decid.*
G *HF, HC, HB, HS*
H *B, BH, BS*
J *SF, SH (and SC), SB*

Study #1: Operable samples (n=11)

Audit Volume (Kozak) vs. Ground Attribute Volume (Predicted in VDYP*): *"VDYP model" bias*

1. Average Volumes/ha and Confidence Interval @ 95% *(Utilization level : 17.5 cm + net merch. less decay only/ Tree class 1,2)*

478——————571——————664

Audit Volume
(16.2% sampling error)

552——————655——————759

Ground Attribute Volume
(predicted in VDYP)
(15.8% sampling error)

2. Ratio Analysis : Ratio of Means @95%

$$R = \frac{\text{average audit volume}}{\text{average ground attribute volume predicted in VDYP}} = 0.87$$

1.0
↓

0.75——————0.87——————0.99

** Since 1.0 is outside the interval, the ratio indicates that there is a significant difference between the audit volume and the ground attribute volume.*

3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons
mean difference = -84.37 m^3/ha
p - value for mean difference = 0.046
**since p - value < α, the difference is significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There were no significant differences within any GTGs.

5. Correlation @95%($\alpha = 0.05$) for all samples
Correlation co-efficient r = 0.650
p - value for correlation co-efficient = 0.030
∴ correlation is significant

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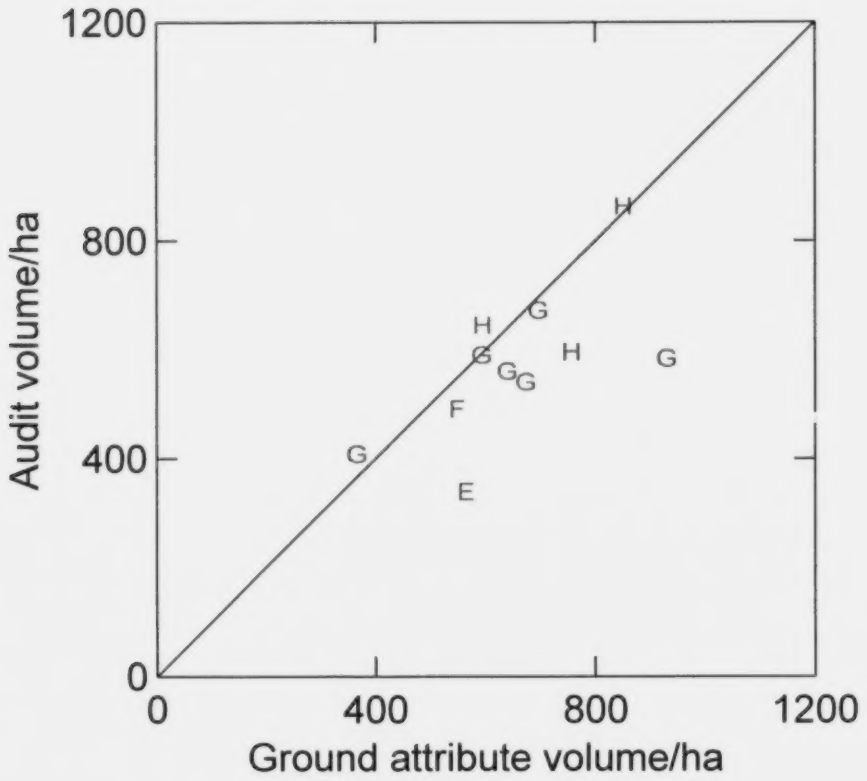
* Study #1 ground attribute volumes reported here were predicted using VDYP version 6.3b. Small volume differences may be observed when data here is compared with the original 1995 analysis, since VDYP has since been revised.

TFL 41 Inventory Audit: Study #1 Operable
Audit Volume (Kozak) vs. Ground Attribute Volume (Predicted in VDYP) by GTG
(Tree Class 1 & 2, less decay only, 17.5cm + dbh)



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Study #1: Operable samples (n=11)

Ground Attribute Volume (predicted in VDYP) vs. Inventory Volume (predicted in VDYP)* : *"Attribute" Bias*

1. Average Volumes/ha and Confidence Interval @ 95% *(Utilization level : 17.5 cm + net merch. less decay only/ Tree class 1,2)*

552——655——759 Ground Attribute Volume (predicted in VDYP) (15.8% sampling error)

539——701——862 Inventory Volume (map label attributes predicted in VDYP) (23.1% sampling error)

2. Ratio Analysis : Ratio of Means @ 95%

$$R = \frac{\text{average ground attribute volume (VDYP)}}{\text{average inventory volume (VDYP)}} = 0.94$$

1.0 ↓

0.78——0.94——1.09

** The ratio indicates there is no significant difference between the ground attribute volume predicted in the VDYP and the inventory volume predicted in the VDYP.*

3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons
mean difference = -45.28 m^3/ha
p - value for mean difference = 0.401
**since p - value > α, the difference is not significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There were no significant differences within any GTGs.

5. Correlation @95%($\alpha = 0.05$) for all samples
Correlation co-efficient r = 0.706
p - value for correlation co-efficient = 0.015
∴ correlation is significant

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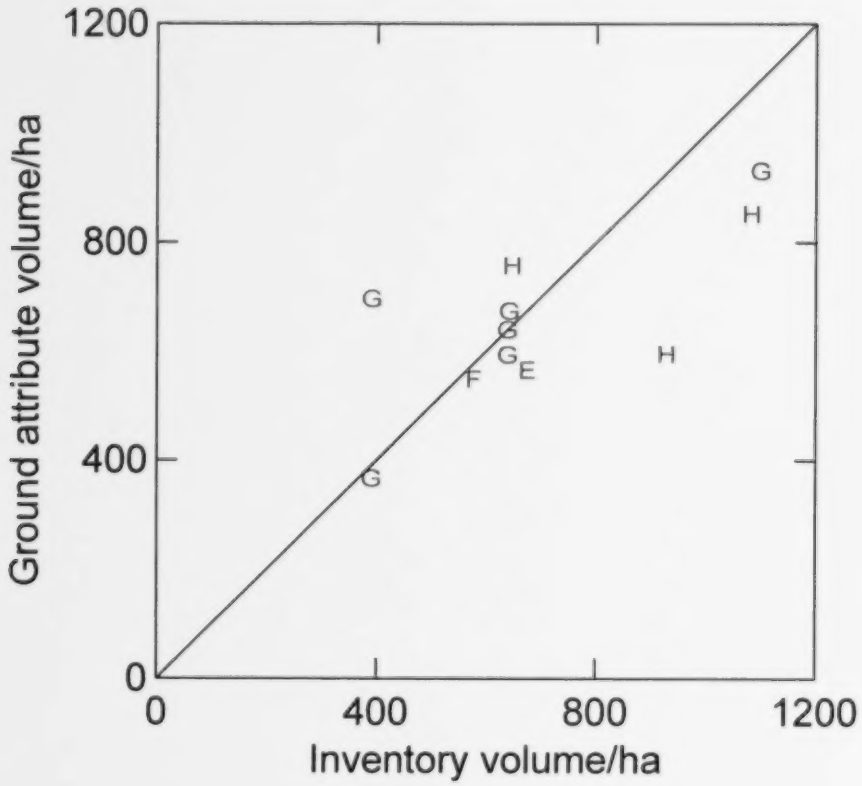
* Study #1 ground attribute and inventory volumes reported here were predicted using VDYP version 6.3b. Small volume differences may be observed when data here is compared with the original 1995 analysis, since VDYP has since been revised.

TFL 41 Inventory Audit: Study #1 Operable Ground Attribute Volume (Predicted in VDYP) vs. Inventory Volume (Predicted in VDYP) by GTG

(Tree Class 1 & 2, less decay only, 17.5cm + dbh)



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H	*B, BH, BS*
J	*SF, SH (and SC), SB*

Study #1: Operable samples (n=11)

Audit Volume (Kozak) vs. Analysis Unit Volume (assuming tree class 1&2 only)

1. Average volumes/ha and confidence interval @ 95%
(Utilization level : tree class 1 & 2, 17.5cm+, less DWB)

412 —— 499 —— 587

Audit Volume
(17.5% sampling error)

557 —— 678 —— 799

Analysis Unit Volume
(17.8% sampling error)

2. Ratio Analysis : Ratio of Means @ 95%

$$R = \frac{\text{average audit volume (Kozak)}}{\text{average analysis unit volume}} = 0.74$$

1.0
↓

0.58 —— 0.74 —— 0.89

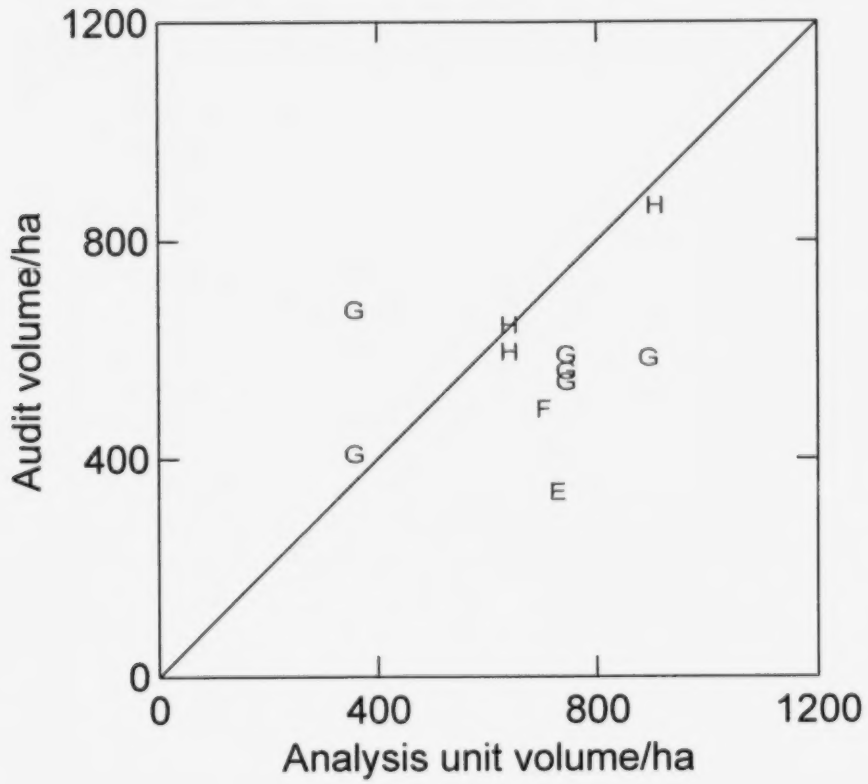
** The ratio indicates there is a significant difference between the audit volume and the analysis unit volume.*

3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons
mean difference = -178.85 m^3/ha
p - value for mean difference = 0.012
**since p - value < α, the difference is significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There were significant differences within GTG H.
(for GTG H: mean difference = -102 m^3/ha; p - value = 0.040; n=3)

5. Correlation @95%($\alpha = 0.05$) for all samples
Correlation co-efficient r = 0.258
p - value for correlation co-efficient = 0.444
∴ correlation is not significant

TFL 41 Inventory Audit: Study#1 Operable
Audit Volume (Kozak) vs. Analysis Unit Volume by GTG
(Tree Class 1 & 2, less DWB, 17.5cm+ dbh)



Letter symbols correspond to map label GTG's as follows:

E	*C, CF, CH*
F	*H (and HPI), H Decid.*
G	*HF, HC, HB, HS*
H	*B, BH, BS*
J	*SF, SH (and SC), SB*

Study #1: Operable samples (n=11)

Audit Volume (Kozak) vs. Analysis Unit Volume (assuming tree class 1,2,3&5)

1. Average volumes/ha and confidence interval @ 95%
(Utilization level : tree class 1,2,3 & 5, 17.5cm+, less DWB)

463 —— 559 —— 654 Audit Volume (17.1% sampling error)

557 —— 678 —— 799 Analysis Unit Volume (17.8% sampling error)

2. Ratio Analysis : Ratio of Means @ 95%

$$R = \frac{\text{average audit volume (Kozak)}}{\text{average analysis unit volume}} = 0.82$$

1.0 ↓

0.64 —— 0.82 —— 1.01

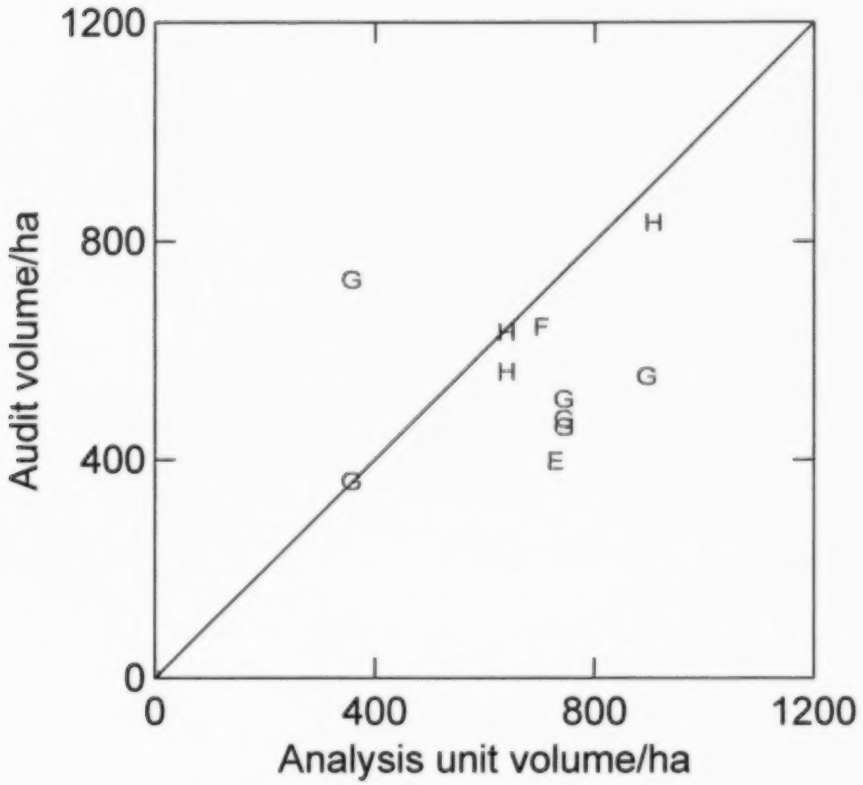
** The ratio indicates there is no significant difference between the audit volume and the analysis unit volume.*

3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons
mean difference = -119.27 m^3/ha
p - value for mean difference = 0.087
**since p - value > α, the difference is not significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There were no significant differences within any GTGs.

5. Correlation @95%($\alpha = 0.05$) for all samples
Correlation co-efficient r = 0.180
p - value for correlation co-efficient = 0.596
∴ correlation is not significant

TFL 41 Inventory Audit: Study #1 Operable
Audit Volume (Kozak) vs. Analysis Unit Volume by GTG
(Tree Class 1,2,3 & 5, less DWB, 17.5cm+ dbh)



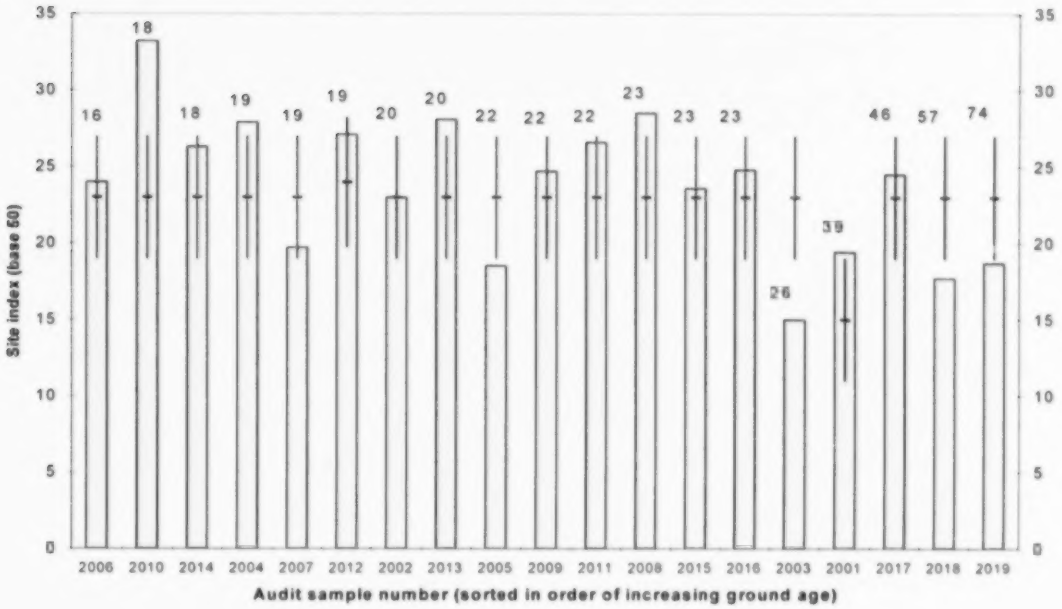
Letter symbols correspond to map label GTG's as follows:

E	*C, CF, CH*
F	*H (and HPI), H Decid.*
G	*HF, HC, HB, HS*
H	*B, BH, BS*
J	*SF, SH (and SC), SB*

Immature Site Index and Classification Assessment

- **37%** of the growth type group assignments from the inventory (ie. map labels) matched the corresponding audit growth type group assignment.

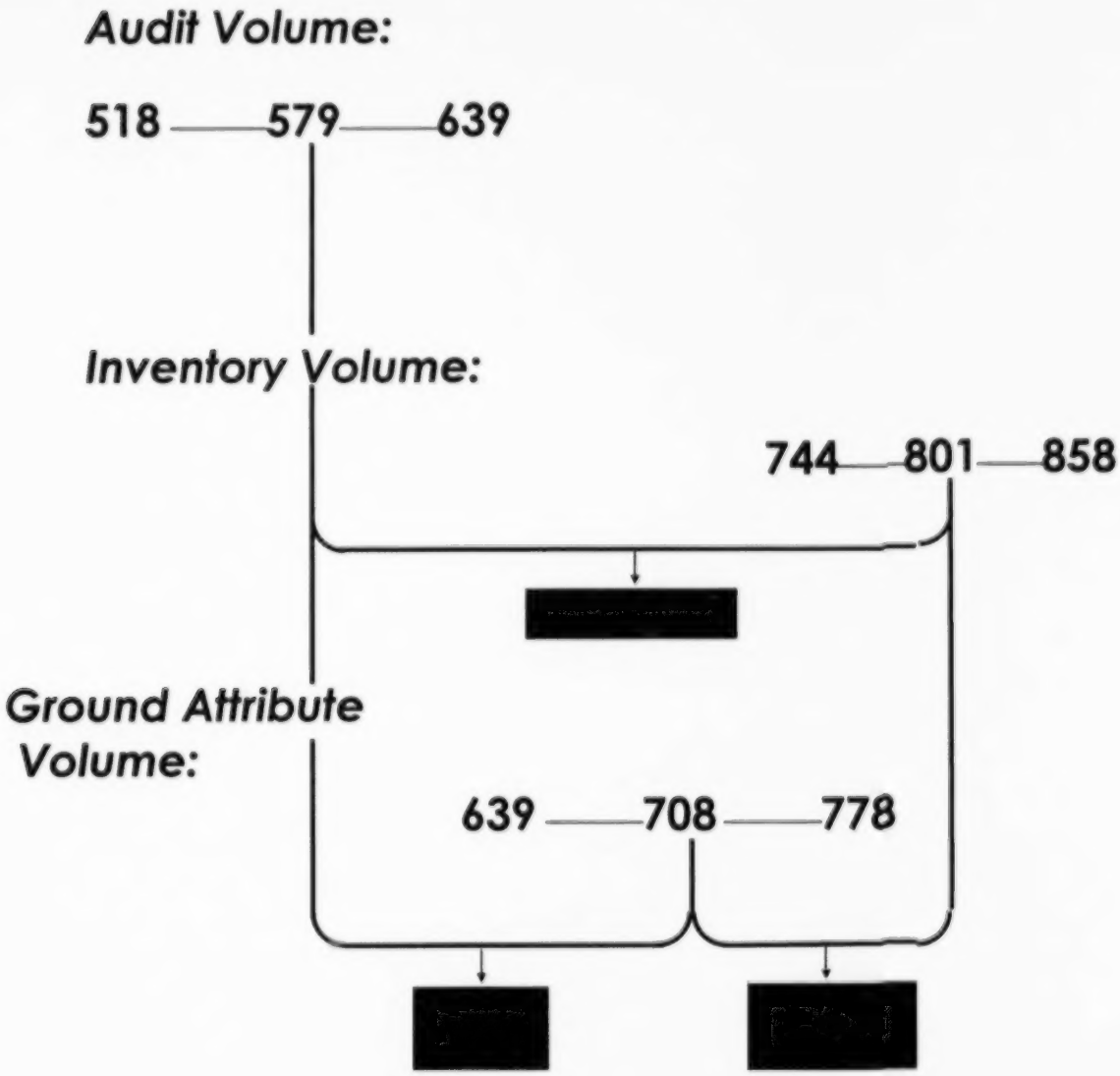
TFL 41 Inventory Audit (Study #1): Comparison of Inventory and Audit Site Index for Immature Samples



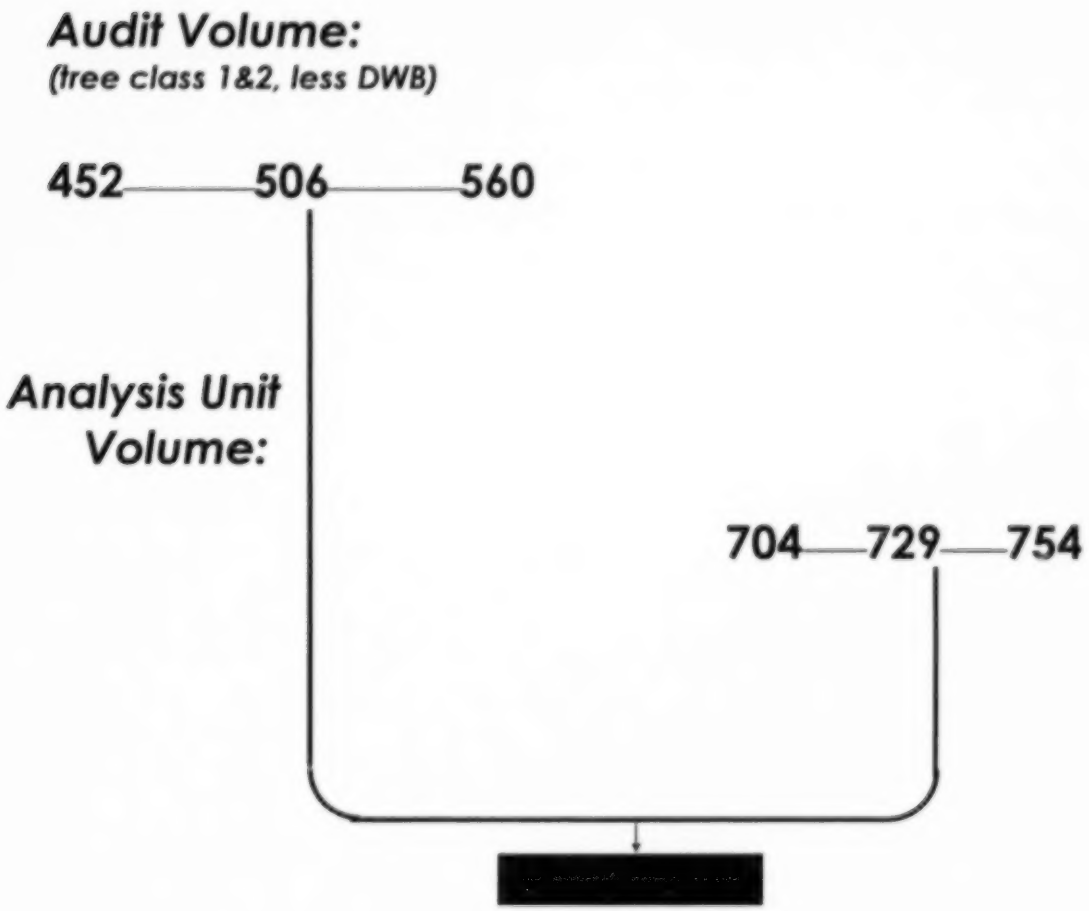
Notes:

- shaded bars correspond to ***audit site index*** values
- tick marks on vertical lines represent ***inventory site index*** (vertical lines have arbitrarily been set at ±5m around site index)
- numbers at the top of the bars corresponds to ground total age
- audit site indices based on BH age where available (using SiteTool)
- inventory site index based on site class midpoint values
- inventory site index was within 5m of the audit site index for 14 out of 19 samples (inventory site index was more than 5m higher than the audit site index for 2 samples and more than 5m lower than the audit SI for 3 samples)
- audit TH species did not match inventory leading species for 6 samples (#2002 2003,2004,2006,2009,2010) (no alternate top height spp were measured).

Study #2: Operable samples (n=30)



Study #2: Operable samples (n=30)



Study #2: Operable samples (n=30)

Audit Volume (Kozak) vs. Inventory Volume (Predicted in VDYP)

1. Average Volumes/ha and Confidence Interval @ 95% *(Utilization level : 17.5 cm + net merch. less decay only/ Tree Class 1,2)*

518——579——639

Audit Volume
(10.5% sampling error)

744——801——858

Inventory Volume
(map label attributes predicted in VDYP)
(7.1% sampling error)

2. Ratio Analysis : Ratio of Means @95%

$$R = \frac{\text{average audit volume}}{\text{average inventory volume}} = 0.72$$

1.0
↓

0.64——0.72——0.81

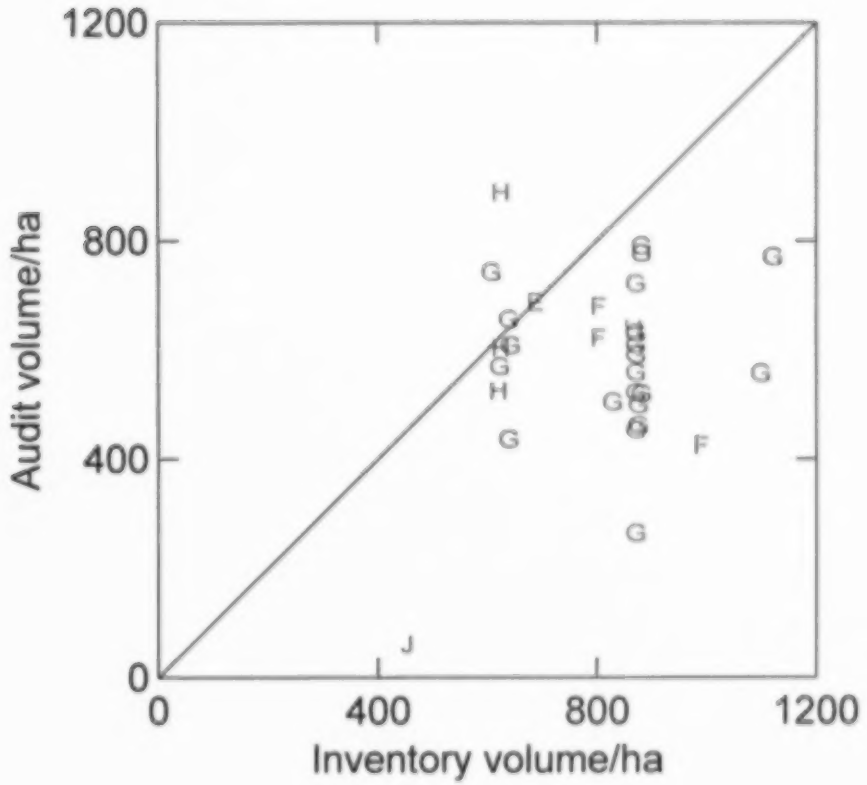
* *Since 1.0 is outside the interval, the ratio indicates that there is a significant difference between the audit volume and the inventory volume.*

3. Paired T Test @ 95% (α=0.05) for all sample polygons
mean difference = -221.88 m^3/ha
p - value for mean difference < 0.001
**since p-value < α, the difference is significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There was a significant differences within GTG G.
(for GTG G: mean difference = -253 m^3/ha; p - value < 0.001; n=21)

5. Correlation @ 95% (α=0.05) for all samples
Correlation co-efficient r = 0.162
p value for correlation co-efficient = 0.391
.: correlation is not significant

TFL 41 Inventory Audit: Study #2 Operable
Audit Volume (Kozak) vs. Inventory Volume (Predicted in VDYP) by GTG
(Tree Class 1 & 2, less decay only, 17.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

E	*C, CF, CH*
F	*H (and HPI), H Decid.*
G	*HF, HC, HB, HS*
H	*B, BH, BS*
J	*SF, SH (and SC), SB*

Study #2: Operable samples (n=30)

Audit Volume (Kozak) vs. Ground Attribute Volume (Predicted in VDYP): *"VDYP model" bias*

1. Average Volumes/ha and Confidence Interval @ 95% *(Utilization level : 17.5 cm + net merch. less decay only/ Tree class 1,2)*

518——579——639

Audit Volume
(10.5% sampling error)

639——708——778

Ground Attribute Volume
(predicted in VDYP)
(9.8% sampling error)

2. Ratio Analysis : Ratio of Means @95%

$$R = \frac{\text{average audit volume}}{\text{average ground attribute volume predicted in VDYP}} = 0.82$$

1.0
↓

0.72——0.82——0.91

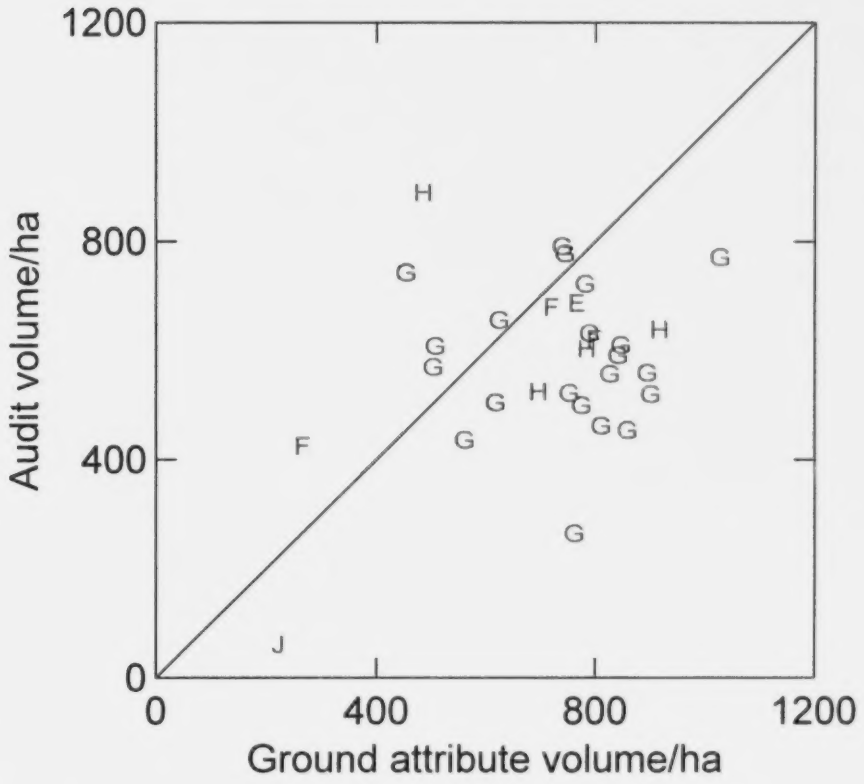
* *Since 1.0 is outside the interval, the ratio indicates that there is a significant difference between the audit volume and the ground attribute volume.*

3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons
mean difference = -129.59 m^3/ha
p - value for mean difference = 0.002
**since p - value < α, the difference is significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There was a significant differences within GTG G.
(for GTG G: mean difference = -160 m^3/ha; p - value = 0.001; n=21)

5. Correlation @95%($\alpha = 0.05$) for all samples
Correlation co-efficient r = 0.312
p - value for correlation co-efficient = 0.093
∴ correlation is not significant

TFL 41 Inventory Audit: Study #2 Operable
Audit Volume (Kozak) vs. Ground Attribute Volume (Predicted in VDYP) by GTG
(Tree Class 1 & 2, less decay only, 17.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

E	*C, CF, CH*
F	*H (and HPI), H Decid.*
G	*HF, HC, HB, HS*
H	*B, BH, BS*
J	*SF, SH (and SC), SB*

Study #2: Operable samples (n=30)

Ground Attribute Volume (predicted in VDYP) vs. Inventory Volume (predicted in VDYP) : *"Attribute" Bias*

1. Average Volumes/ha and Confidence Interval @ 95% *(Utilization level : 17.5 cm + net merch. less decay only/ Tree class 1,2)*

639——708——778 Ground Attribute Volume (predicted in VDYP) (9.8% sampling error)

744——801——858 Inventory Volume (map label attributes predicted in VDYP) (7.1% sampling error)

2. Ratio Analysis : Ratio of Means @ 95%

$$R = \frac{\text{average ground attribute volume (VDYP)}}{\text{average inventory volume (VDYP)}} = 0.88$$

1.0 ↓

0.82——0.88——0.95

** The ratio indicates there is a significant difference between the ground attribute volume predicted in the VDYP and the inventory volume predicted in the VDYP.*

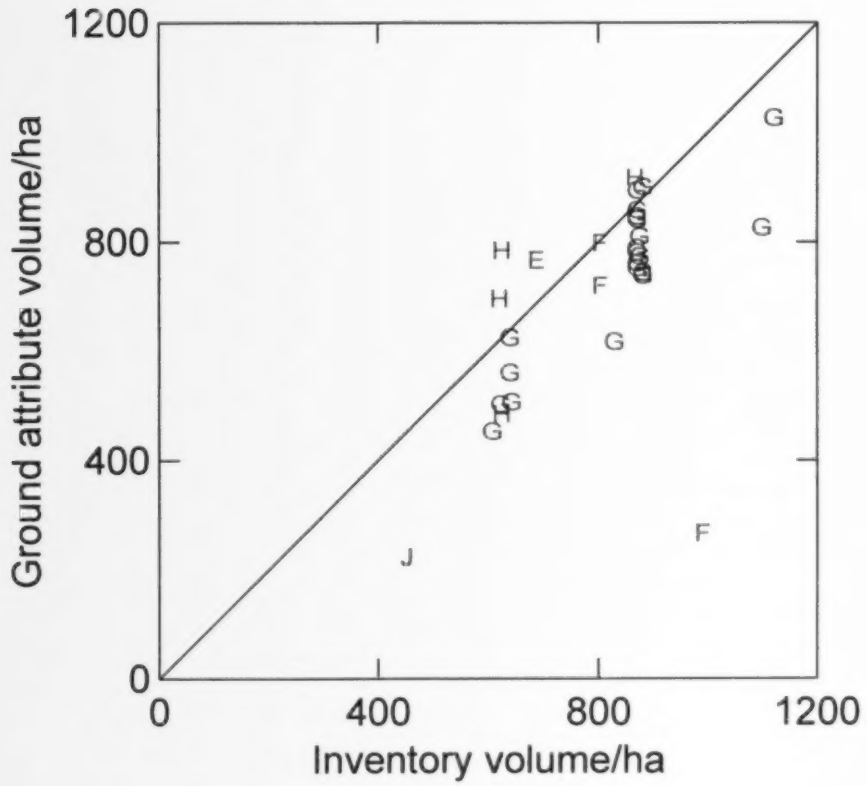
3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons
mean difference = -92.29 m^3/ha
p - value for mean difference = 0.003
**since p - value < α, the difference is significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There was a significant differences within GTG G.
(for GTG G: mean difference = -93 m^3/ha; p - value < 0.001; n=21)

5. Correlation @95%($\alpha = 0.05$) for all samples
Correlation co-efficient r = 0.610
p - value for correlation co-efficient < 0.001
.: correlation is significant

TFL 41 Inventory Audit: Study #2 Operable Ground Attribute Volume (Predicted in VDYP) vs. Inventory Volume (Predicted in VDYP) by GTG

(Tree Class 1 & 2, less decay only, 17.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

- E *C, CF, CH*
- F *H (and HPI), H Decid.*
- G *HF, HC, HB, HS*
- H *B, BH, BS*
- J *SF, SH (and SC), SB*

Study #2: Operable samples (n=30)

Audit Volume (Kozak) vs. Analysis Unit Volume (assuming tree class 1&2 only)

1. Average volumes/ha and confidence interval @ 95%
(Utilization level : tree class 1 & 2, 17.5cm+, less DWB)

452——506——560

Audit Volume
(10.7% sampling error)

704—729—754

Analysis Unit Volume
(3.5% sampling error)

2. Ratio Analysis : Ratio of Means @ 95%

$$R = \frac{\text{average audit volume (Kozak)}}{\text{average analysis unit volume}} = 0.69$$

1.0
↓

0.62——0.69——0.77

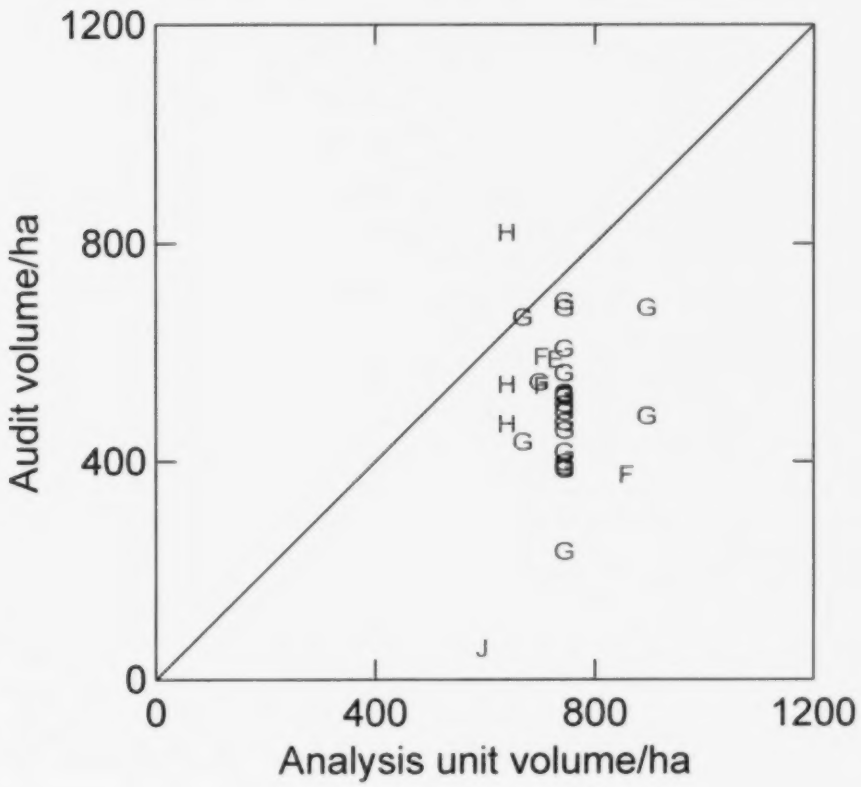
** The ratio indicates there is a significant difference between the audit volume and the analysis unit volume.*

3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons
mean difference = -223.4 m^3/ha
p - value for mean difference < 0.001
**since p - value < α, the difference is significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There was a significant difference within GTG G.
(for GTG G: mean difference = -241 m^3/ha; p - value < 0.001; n=21)

5. Correlation @95%($\alpha = 0.05$) for all samples
Correlation co-efficient r = 0.089
p - value for correlation co-efficient = 0.641
∴ correlation is not significant

TFL 41 Inventory Audit: Study#2 Operable
Audit Volume (Kozak) vs. Analysis Unit Volume by GTG
(Tree Class 1 & 2, less DWB, 17.5cm+ dbh)



Letter symbols correspond to map label GTG's as follows:

E	*C, CF, CH*
F	*H (and HPI), H Decid.*
G	*HF, HC, HB, HS*
H	*B, BH, BS*
J	*SF, SH (and SC), SB*

Study #2: Operable samples (n=30)

Audit Volume (Kozak) vs. Analysis Unit Volume (assuming tree class 1,2,3&5)

1. Average volumes/ha and confidence interval @ 95%
(Utilization level : tree class 1,2,3 & 5, 17.5cm+, less DWB)

497 —— 549 —— 602

Audit Volume
(9.6% sampling error)

704 — 729 — 754

Analysis Unit Volume
(3.5% sampling error)

2. Ratio Analysis : Ratio of Means @ 95%

$$R = \frac{\text{average audit volume (Kozak)}}{\text{average analysis unit volume}} = 0.75$$

1.0
↓

0.68 —— 0.75 —— 0.83

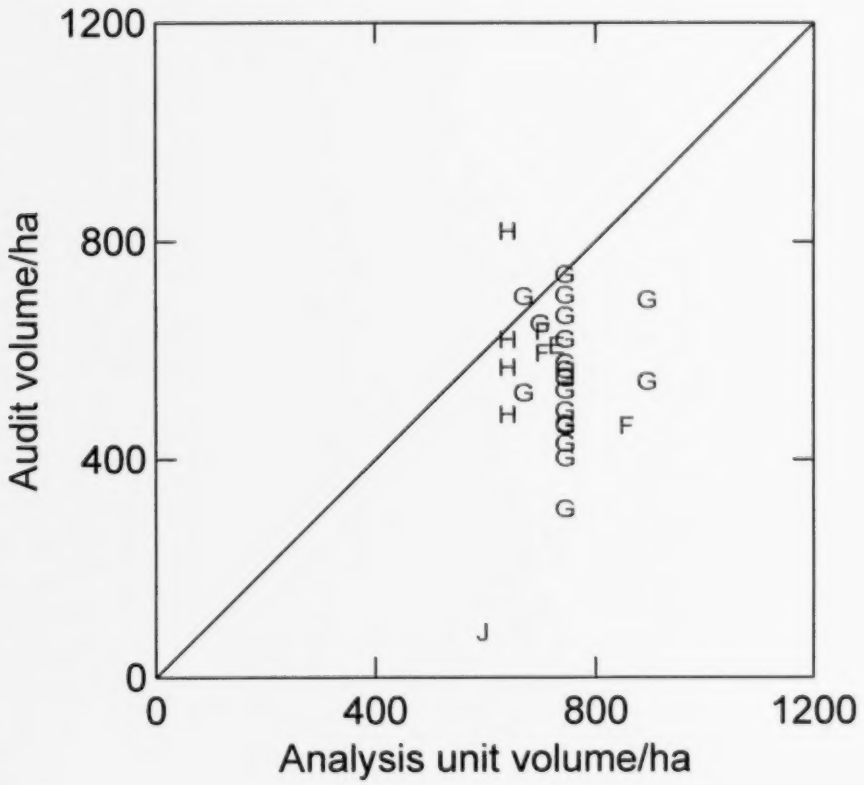
** The ratio indicates there is a significant difference between the audit volume and the analysis unit volume.*

3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons
mean difference = -179.87 m^3/ha
p - value for mean difference < 0.001
**since p - value < α, the difference is significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There was a significant difference within GTG G.
(for GTG G: mean difference = -195 m^3/ha; p - value < 0.001; n=21)

5. Correlation @95%($\alpha = 0.05$) for all samples
Correlation co-efficient r = 0.111
p - value for correlation co-efficient = 0.561
∴ correlation is not significant

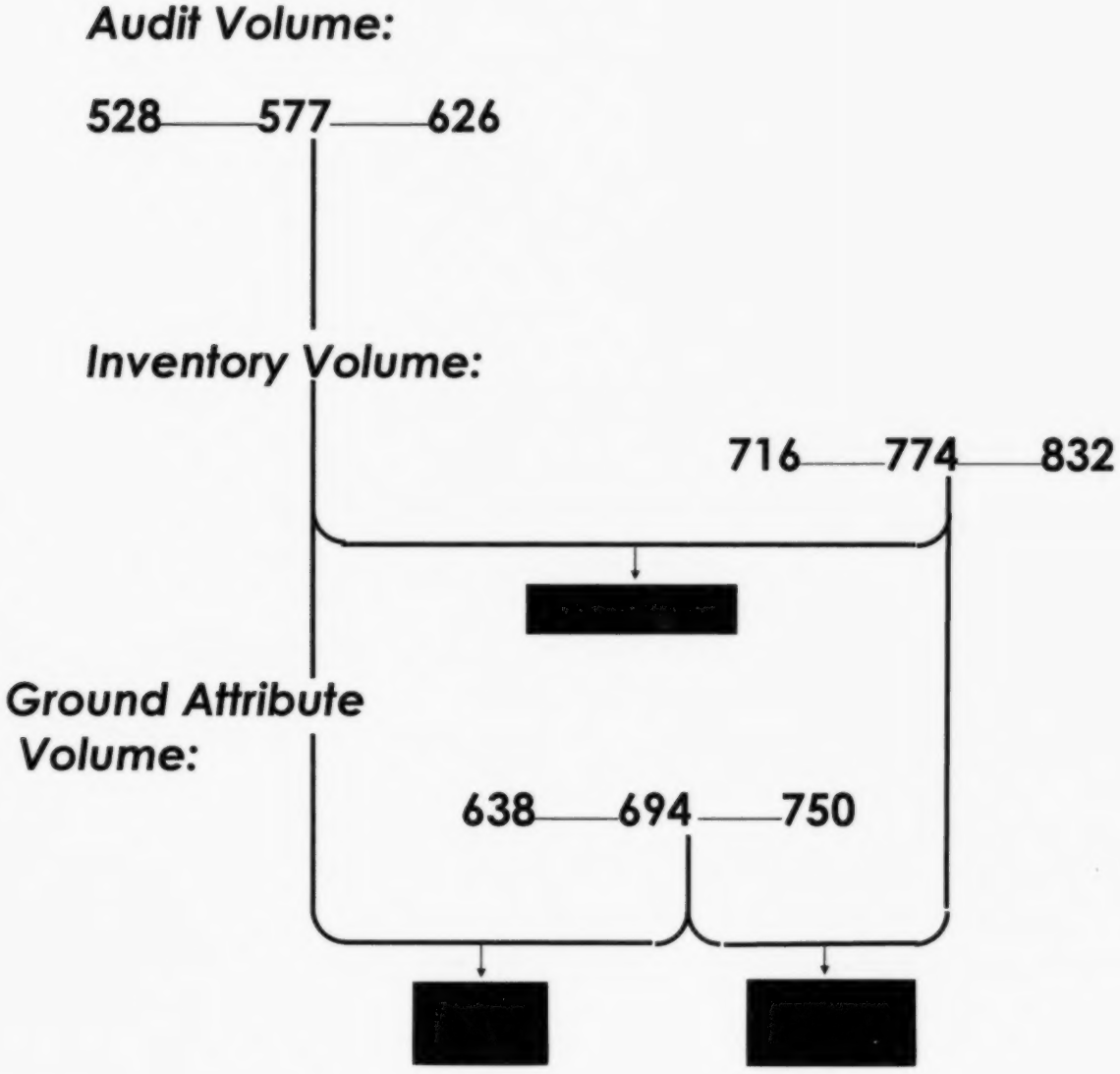
TFL 41 Inventory Audit: Study #2 Operable
Audit Volume (Kozak) vs. Analysis Unit Volume by GTG
(Tree Class 1,2,3 & 5, less DWB, 17.5cm+ dbh)



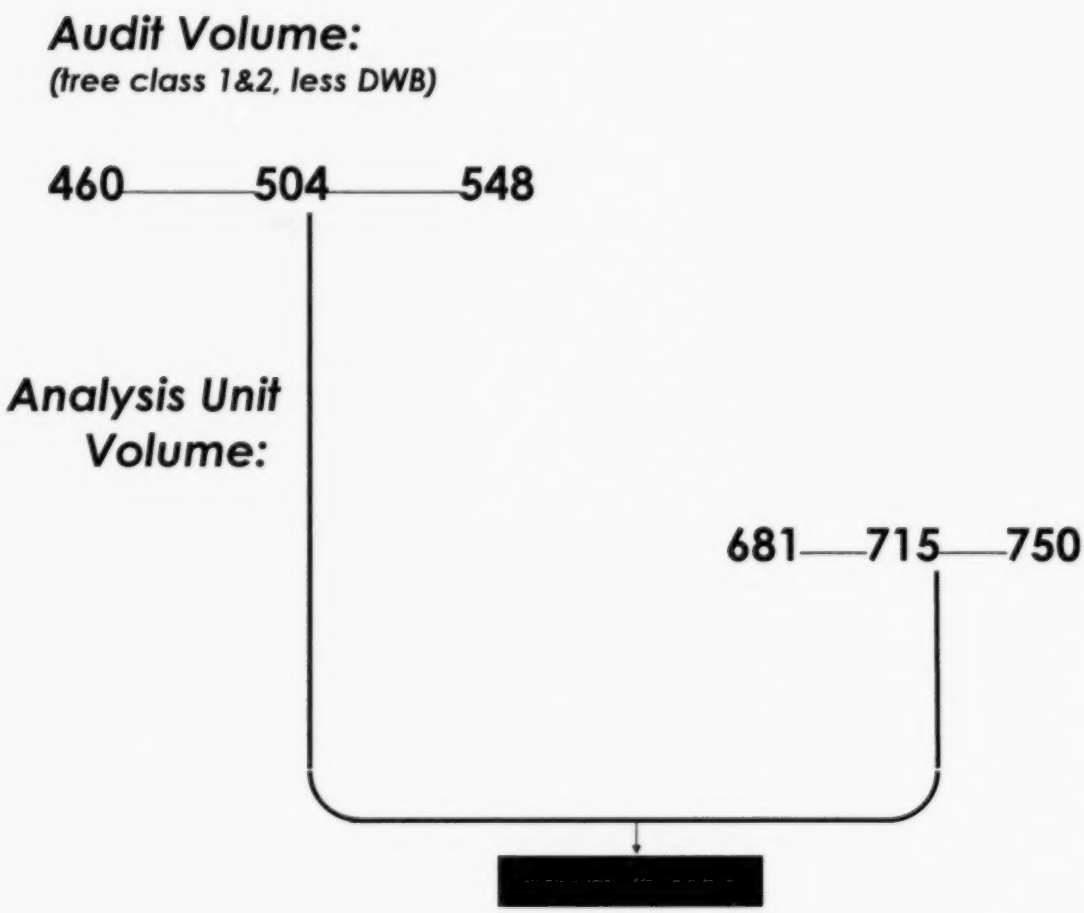
Letter symbols correspond to map label GTG's as follows:

E	*C, CF, CH*
F	*H (and HPI), H Decid.*
G	*HF, HC, HB, HS*
H	*B, BH, BS*
J	*SF, SH (and SC), SB*

Combined Studies #1&2 for TFL 41: Operable samples (n=41)



Combined Studies #1&2 for TFL 41: Operable samples (n=41)



Combined Studies #1&2 for TFL 41: Operable samples (n=41)

Audit Volume (Kozak) vs. Inventory Volume (Predicted in VDYP)

1. Average Volumes/ha and Confidence Interval @ 95% *(Utilization level : 17.5 cm + net merch. less decay only/ Tree Class 1,2)*

528——577——626

Audit Volume
(8.5% sampling error)

716——774——832

Inventory Volume
(map label attributes predicted in VDYP)
(7.5% sampling error)

2. Ratio Analysis : Ratio of Means @95%

$$R = \frac{\text{average audit volume}}{\text{average inventory volume}} = 0.75$$

1.0
↓

0.67——0.75——0.82

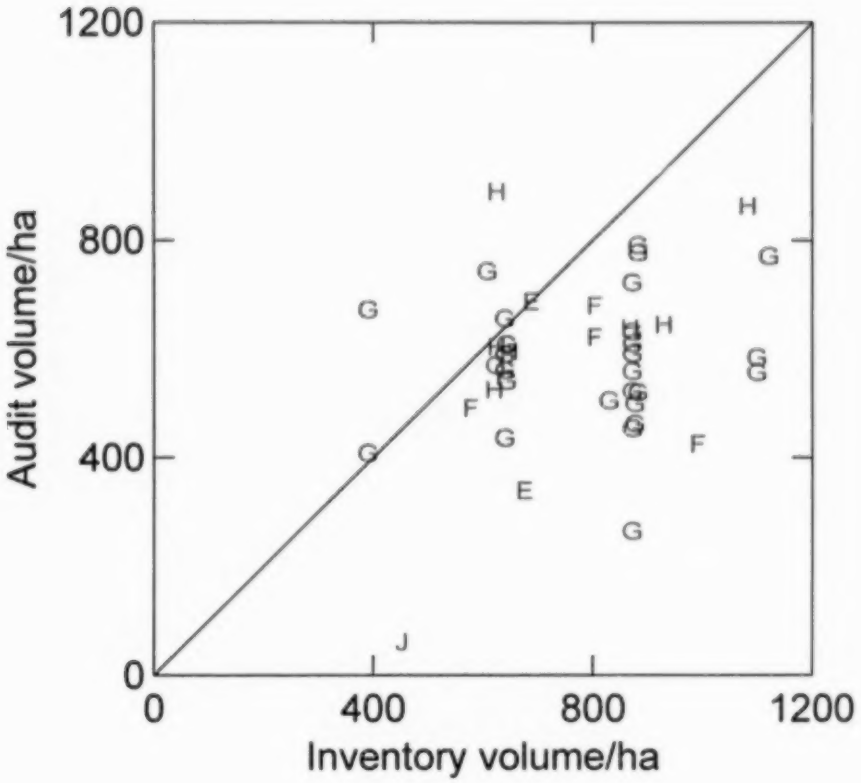
* *Since 1.0 is outside the interval, the ratio indicates that there is a significant difference between the audit volume and the inventory volume.*

3. Paired T Test @ 95% (α=0.05) for all sample polygons
mean difference = -197.14 m^3/ha
p - value for mean difference < 0.001
**since p-value < α, the difference is significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There was a significant differences within GTG G.
(for GTG G: mean difference = -213 m^3/ha; p - value < 0.001; n=27)

5. Correlation @ 95% (α=0.05) for all samples
Correlation co-efficient r = 0.258
p value for correlation co-efficient = 0.104
∴ correlation is not significant

TFL 41 Inventory Audit: Studies #1&2 Combined
Audit Volume (Kozak) vs. Inventory Volume (Predicted in VDYP) by GTG
(Tree Class 1 & 2, less decay only, 17.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

E	*C, CF, CH*
F	*H (and HPI), H Decid.*
G	*HF, HC, HB, HS*
H	*B, BH, BS*
J	*SF, SH (and SC), SB*

Combined Studies #1&2 for TFL 41: Operable samples (n=41)

Audit Volume (Kozak) vs. Ground Attribute Volume (Predicted in VDYP): *"VDYP model" bias*

1. Average Volumes/ha and Confidence Interval @ 95% *(Utilization level : 17.5 cm + net merch. less decay only/ Tree class 1,2)*

528——577——626

Audit Volume
(8.5% sampling error)

638——694——750

Ground Attribute Volume
(predicted in VDYP)
(8.1% sampling error)

2. Ratio Analysis : Ratio of Means @95%

$R = \frac{\text{average audit volume}}{\text{average ground attribute volume predicted in VDYP}} = 0.83$

1.0
↓

0.75——0.83——0.91

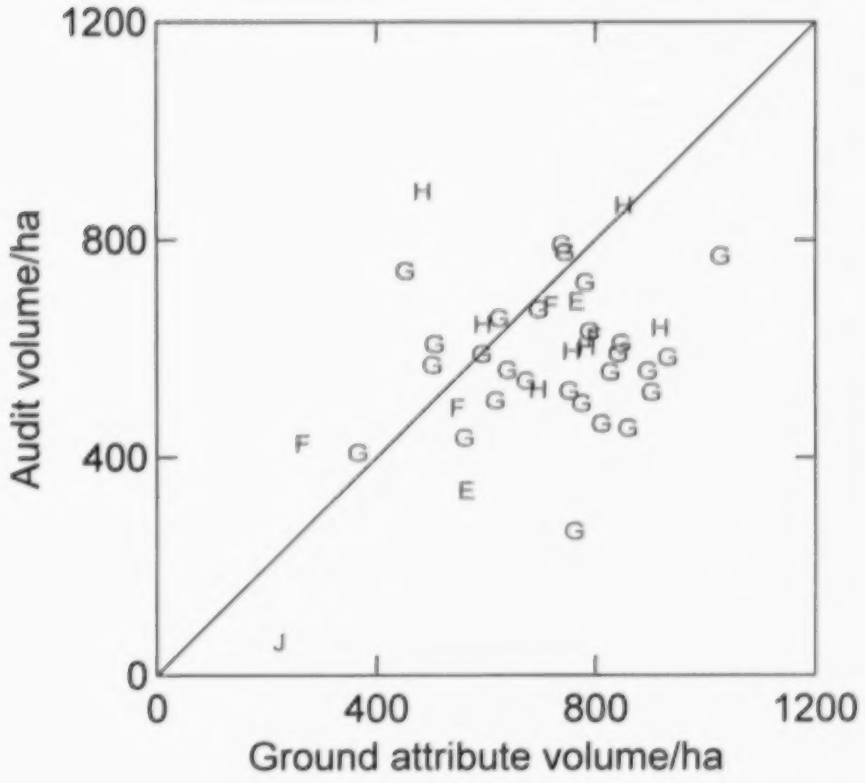
* *Since 1.0 is outside the interval, the ratio indicates that there is a significant difference between the audit volume and the ground attribute volume.*

3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons
mean difference = -117.46 m^3/ha
p - value for mean difference < 0.001
**since p - value < α, the difference is significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There was a significant differences within GTG G.
(for GTG G: mean difference = -145 m^3/ha; p - value < 0.001; n=27)

5. Correlation @95%($\alpha = 0.05$) for all samples
Correlation co-efficient r = 0.378
p - value for correlation co-efficient = 0.015
∴ correlation is significant

TFL 41 Inventory Audit: Studies #1&2 Combined
Audit Volume (Kozak) vs. Ground Attribute Volume (Predicted in VDYP) by GTG
(Tree Class 1 & 2, less decay only, 17.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

E	*C, CF, CH*
F	*H (and HPI), H Decid.*
G	*HF, HC, HB, HS*
H	*B, BH, BS*
J	*SF, SH (and SC), SB*

Combined Studies #1&2 for TFL 41: Operable samples (n=41)

Ground Attribute Volume (predicted in VDYP) vs. Inventory Volume (predicted in VDYP) : *"Attribute" Bias*

1. Average Volumes/ha and Confidence Interval @ 95% *(Utilization level : 17.5 cm + net merch. less decay only/ Tree class 1,2)*

638——694——750 Ground Attribute Volume (predicted in VDYP) (8.1% sampling error)

716——774——832 Inventory Volume (map label attributes predicted in VDYP) (7.5% sampling error)

2. Ratio Analysis : Ratio of Means @ 95%

$$R = \frac{\text{average ground attribute volume (VDYP)}}{\text{average inventory volume (VDYP)}} = 0.90$$

1.0 ↓

0.84——0.90——0.96

** The ratio indicates there is a significant difference between the ground attribute volume predicted in the VDYP and the inventory volume predicted in the VDYP.*

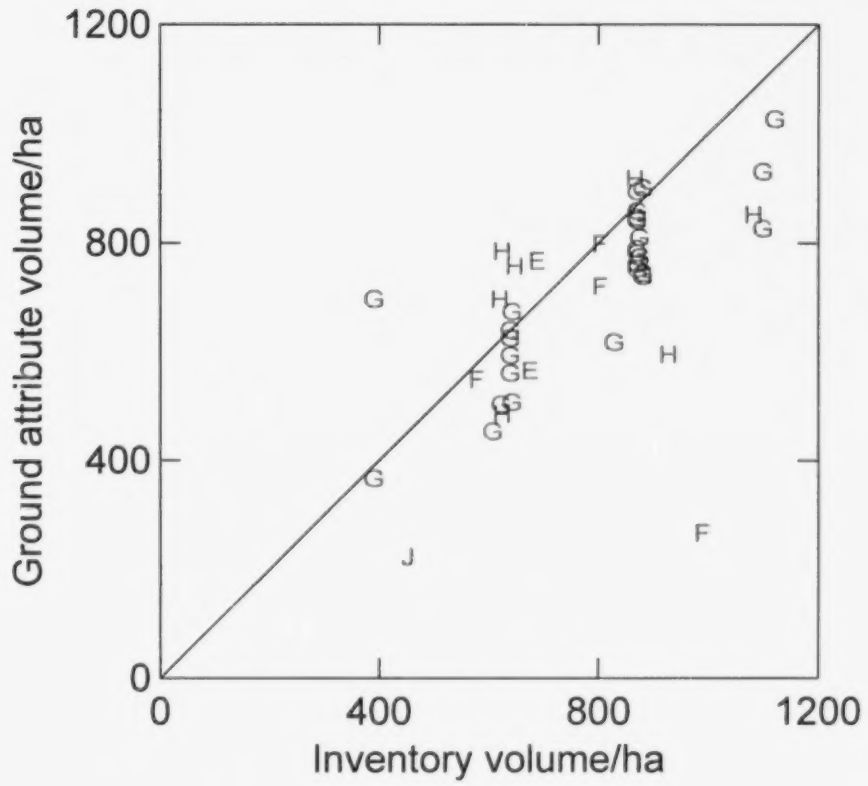
3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons
mean difference = -79.68 m^3/ha
p - value for mean difference = 0.002
**since p - value < α, the difference is significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There was a significant differences within GTG G.
(for GTG G: mean difference = -69 m^3/ha; p - value = 0.002; n=27)

5. Correlation @95%($\alpha = 0.05$) for all samples
Correlation co-efficient r = 0.621
p - value for correlation co-efficient < 0.001
∴ correlation is significant

TFL 41 Inventory Audit: Studies #1&2 Combined Ground Attribute Volume (Predicted in VDYP) vs. Inventory Volume (Predicted in VDYP) by GTG

(Tree Class 1 & 2, less decay only, 17.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

E	*C, CF, CH*
F	*H (and HPI), H Decid.*
G	*HF, HC, HB, HS*
H	*B, BH, BS*
J	*SF, SH (and SC), SB*

Combined Studies #1&2 for TFL 41: Operable samples (n=41)

Audit Volume (Kozak) vs. Analysis Unit Volume (assuming tree class 1&2 only)

1. Average volumes/ha and confidence interval @ 95%
(Utilization level : tree class 1 & 2, 17.5cm+, less DWB)

460——504——548

Audit Volume
(8.7% sampling error)

681—715—750

Analysis Unit Volume
(4.8% sampling error)

2. Ratio Analysis : Ratio of Means @ 95%

$$R = \frac{\text{average audit volume (Kozak)}}{\text{average analysis unit volume}} = 0.70$$

1.0
↓

0.64——0.70——0.77

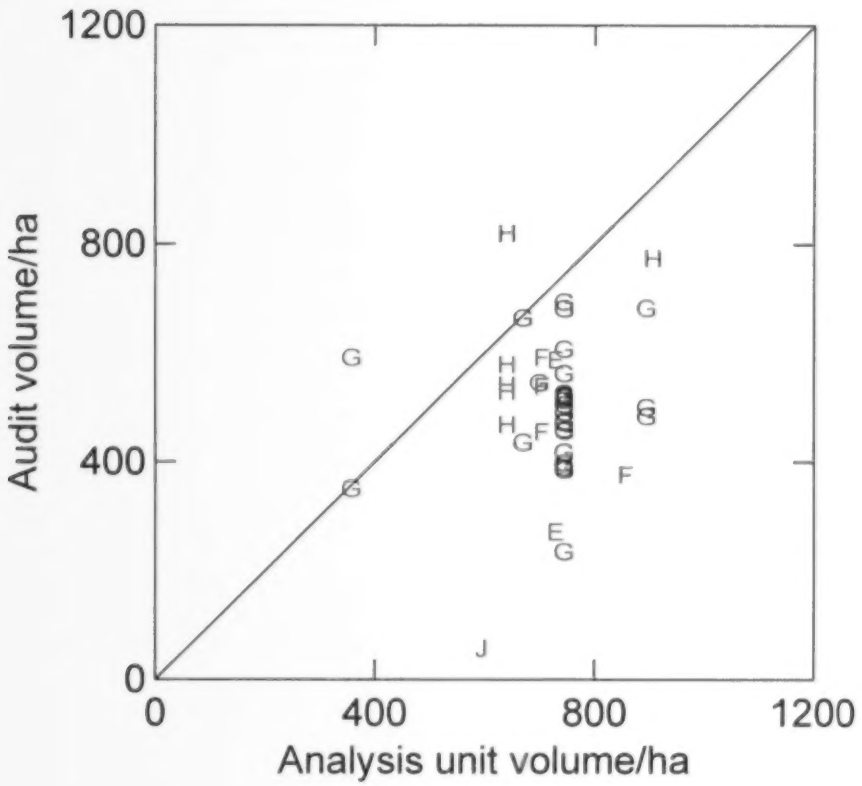
** The ratio indicates there is a significant difference between the audit volume and the analysis unit volume.*

3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons
mean difference = -211.45 m^3/ha
p - value for mean difference < 0.001
**since p - value < α, the difference is significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There was a significant difference within GTG G.
(for GTG G: mean difference = -223 m^3/ha; p - value < 0.001; n=27)

5. Correlation @95%($\alpha = 0.05$) for all samples
Correlation co-efficient r = 0.145
p - value for correlation co-efficient = 0.365
∴ correlation is not significant

TFL 41 Inventory Audit: Studies #1&2 Combined
Audit Volume (Kozak) vs. Analysis Unit Volume by GTG
(Tree Class 1 & 2, less DWB, 17.5cm+ dbh)



Letter symbols correspond to map label GTG's as follows:

E	*C, CF, CH*
F	*H (and HPI), H Decid.*
G	*HF, HC, HB, HS*
H	*B, BH, BS*
J	*SF, SH (and SC), SB*

Combined Studies #1&2 for TFL 41: Operable samples (n=41)

Audit Volume (Kozak) vs. Analysis Unit Volume (assuming tree class 1,2,3&5)

1. Average volumes/ha and confidence interval @ 95%
(Utilization level : tree class 1,2,3 & 5, 17.5cm+, less DWB)

508 —— 552 —— 596

Audit Volume
(8.0% sampling error)

681 — 715 — 750

Analysis Unit Volume
(4.8% sampling error)

2. Ratio Analysis : Ratio of Means @ 95%

$$R = \frac{\text{average audit volume (Kozak)}}{\text{average analysis unit volume}} = 0.77$$

1.0
↓

0.70 —— 0.77 —— 0.84

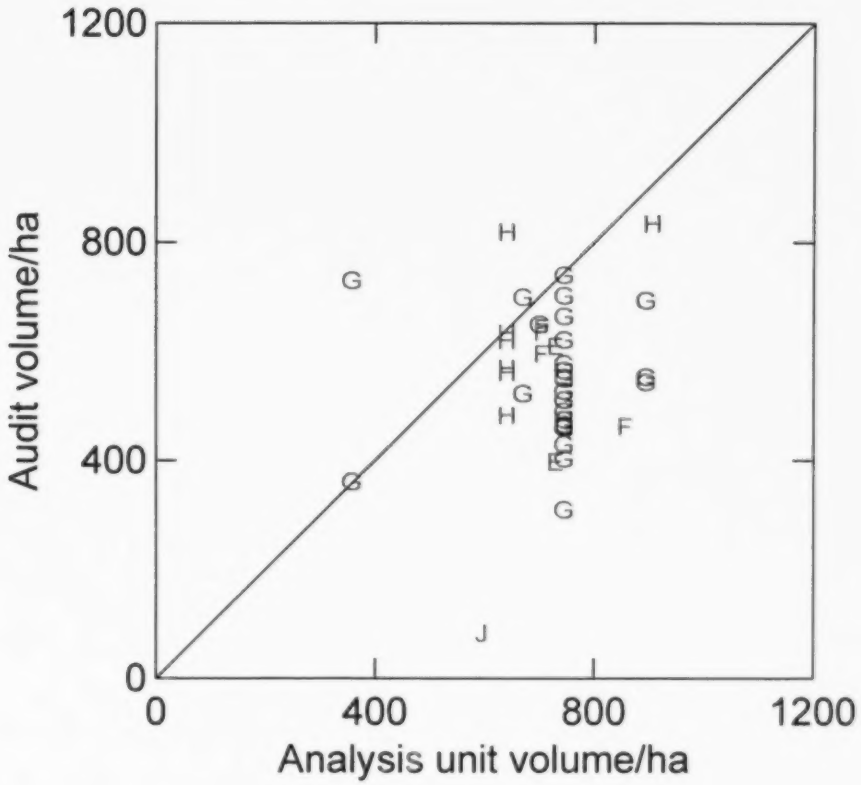
** The ratio indicates there is a significant difference between the audit volume and the analysis unit volume.*

3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons
mean difference = -163.61 m^3/ha
p - value for mean difference < 0.001
**since p - value < α the difference is significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There was a significant difference within GTG G.
(for GTG G: mean difference = -180 m^3/ha; p - value < 0.001; n=27)

5. Correlation @95%($\alpha = 0.05$) for all samples
Correlation co-efficient r = 0.119
p - value for correlation co-efficient = 0.457
∴ correlation is not significant

TFL 41 Inventory Audit: Studies #1&2 Combined
Audit Volume (Kozak) vs. Analysis Unit Volume by GTG
(Tree Class 1,2,3 & 5, less DWB, 17.5cm+ dbh)



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F	*H (and HPI), H Decid.*
G	*HF, HC, HB, HS*
H	*B, BH, BS*
J	*SF, SH (and SC), SB*